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The study of ferroelectric, magnetic and magnetoelectric properties of Multiferroic $Pb(Fe_{0.5}Ti_{0.5})O_3$ nanoparticles

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Abstract

Multiferroic $Pb(Fe_{0.5}Ti_{0.5})O_3$ is a system which has coupled co-existence of ferroelecticity and ferromagnetism at room temperature. We have been successful in synthesizing multiferroic $Pb(Fe_{0.5}Ti_{0.5})O_3$ nanoparticles of average size 36nm using wet chemical route and studied the ferromagnetic, ferroelectric and multiferroic properties of this system. It is observed that the nanoparticles also possess ferroelectricity, ferromagnetism and menetoelectric coupling at room temperature. This study could be useful in small scale devices employing multiferroicity, for example multi-state memory devices.

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Keywords; Ferroelectricity; multiferroics

1. Introduction

Multiferroics are the materials which possess more than one ferroic order parameters (for example ferroelectricity and ferromagnetism) in the same phase and there is a coupling between the two. Multiferroic materials have attracted immense interest among researchers owing to the interesting physics involved and their capability to provide extra degree of freedom in device operation. The pre-requisites for their implementation in devices are coupled co-existence of ferroelectricity and ferromagnetism at room temperature. However there are a few materials such as multiferroic $Pb(Fe_{0.5}Ti_{0.5})O_3$ system which show a coupled coexistence of ferroelectricity and ferromagnetism at room temperature (Palkar et al, 2005). For incorporating such novel functionalities in Micro or Nano

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Electromechanical Systems (MEMS & NEMS), it is important to study these properties in nano sized multiferroic systems. This paper reports the experimental results on ferroelectric, ferromagnetic and multiferroic properties of multiferroics $Pb(Fe_{0.5}Ti_{0.5})O_3$ nanopartices.

2. Experimental

Fine particles of Multiferroic $Pb(Fe_{0.5}Ti_{0.5})O_3$ system were synthesized using wet chemical route. The nitrates of the cations are mixed together and co-precipitated using NH_4OH as a precipitating agent. PH of the final solution is maintained above 9 for the complete precipitation to occur and the concentration of the solution is adjusted to obtain the fine particles. The precipitant so obtained is washed properly using de-ionized water till the PH falls to 7. Now the filtered precipitant is dried under IR lamp and ground. Since phase formation occurs around 500^{o}C so we calcined the material at 500^{o}C, 550^{o}C, 750^{o}C and 800^{o}C for 0.5h with a ramp rate of 10^{o}C/min to get samples of different sizes. The finite size effect studies on magnetic properties of these samples (Snehlata Gupta et al., 2011) shows that samples with 36nm (corresponding to the calcinations temperature 800^{0}C) gives good magnetic properties. It is known that the particle size grow with the calcination temperature (soma at el, 1995), also Pb losses may occur at higher calcinations temperatures so we concentrated on the measurement of multiferroic properties at 36nm nanoparticle size.

The fine particles of $Pb(Fe_{0.5}Ti_{0.5})O_3$ are characterized by using various techniques. XRD (XPERT-PRO diffractometer using Cu-Kα radiation) is used for crystal structure and phase analysis. Ferroelectric loop tracer (Radiant technology RT6000) is used to obtain ferroelectric hysteresis loop. Vibrating sample magnetometer (Quantum Design PPMS) is used for studying magnetic properties.

3. Results and discussion

The XRD pattern (figure 1.) revealed that the fine particles are more or less single phase with very small impurity phase present.

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Fig. 1. XRD pattern of $Pb(Fe_{0.5}Ti_{0.5})O_3$ powder sample at room temperature.

The average crystal–grain size (coherently diffracting domain size) of the powders was estimated from the (111) reflections, by means of the Scherrer equation,

$$d = k\lambda / (\beta\cos\Theta) \quad (1)$$

Where d is the average diameter of the crystal grains, k is a particle shape factor, λ is the wavelength of Cu-Kα radiation, Θ is the corresponding Bragg angle and β is the full width of half maxima of the peak after correcting for peak broadening which is caused by the diffractometer. The average grain size is estimated to be 35.6nm.

The result of the magnetic measurements obtained by VSM is shown in figure. 2. It is found that the saturated magnetization value (M_S emu/g) is ~5.187emu/g at 1Tesla of applied magnetic field (H).

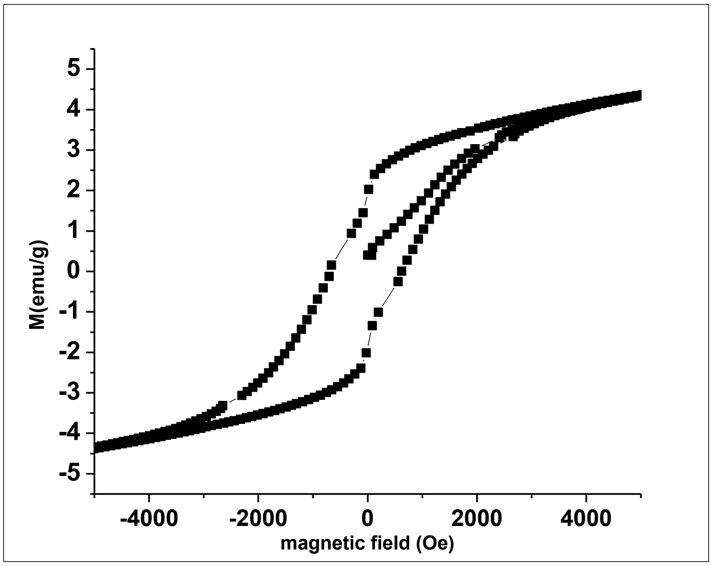

Figure 1. M-H plot at room temperature.

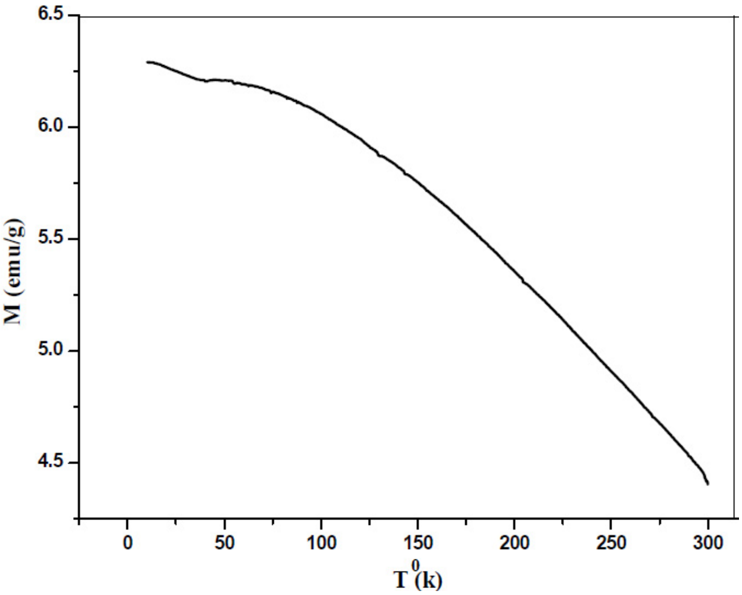

Figure 2. M-T plot at 5 KOe H field.

Figure 2 shows magnetic moment Vs. Temperature plot. It is clear from M-H and M-T plots that the particles show ferromagnetism.

Ferroelectric hysteresis loop is shown in fig. 3, which confirms the ferroelectric characteristic of the fine particles. For studying magneto-electric coupling in the nanoparticles, the change in the electric polarization is seen with externally applied magnetic field.

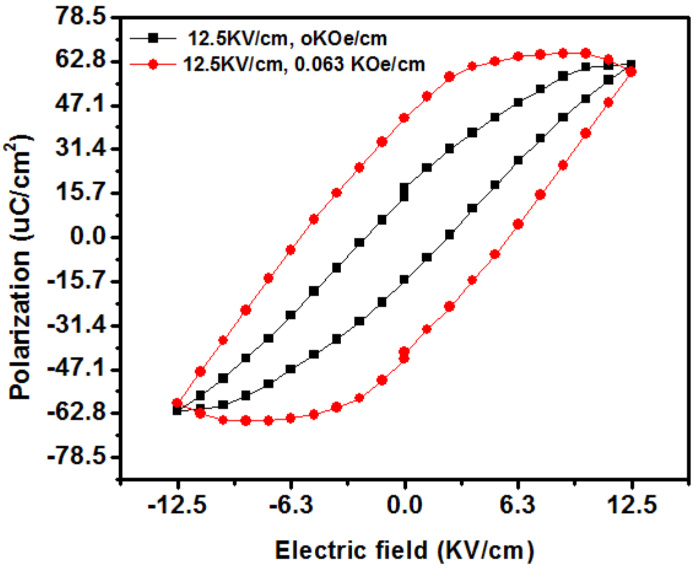

Figure 3. Ferroelectric hysteresis loop with and without externally applied magnetic field.

Fig. 3 shows that the value of remainant polarization (P_r) increases with the application of magnetic field hence the P_r/P_s values also improves with magnetic field. This confirms the room temperature multiferroism of the nanopartiles.

4. Conclusions

We have been successful in synthesizing multiferroic $Pb(Fe_{0.5}Ti_{0.5})O_3$ nanoparticles of average size 36nm using wet chemical route. Ferroelectric, ferromagnetic and multiferroic (co-existance of ferroelectricity and ferromagnetism) properties of the multiferroic $Pb(Fe_{0.5}Ti_{0.5})O_3$ nano particles have been studied. The study indicates that $Pb(Fe_{0.5}Ti_{0.5})O_3$ nanoparticles also shows multiferroism at room temperature. at of size possible properties. The results could be useful while integrating multiferroic nano devices.

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